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March 24, 2000

BOX: PATENT APPLICATION
Assistant Commissioner for Patents
Washington, D.C. 20231

Re: Application of Hideo MIURA and Kazumi KUBO
OPTICAL COMPONENT FIXING METHOD AND OPTICAL COMPONENT SUPPORT
Our Reference: Q56556

Dear Sir:

Attached hereto is the application identified above including the specification, claims, executed Declaration and Power of Attorney, two (2) sheets of drawings, one (1) priority document, Information Disclosure Statement and PTO Form 1449 with references and executed Assignment and PTO Form 1595.

The Government filing fee is calculated as follows:

Total Claims	8 - 20 =	0 x $18 =	$ 000.00
Independent Claims	2 - 3 =	0 x $78 =	$ 000.00
Base Filing Fee	($690.00)		$ 690.00
Multiple Dep. Claim Fee	($260.00)		$ 260.00
TOTAL FILING FEE			**$ 950.00**
Recordation of Assignment Fee			$ 40.00
TOTAL U.S. GOVERNMENT FEE			**$ 990.00**

Checks for the statutory filing fee of **$ 950.00** and Assignment recordation fee of **$ 40.00** are attached. You are also directed and authorized to charge or credit any difference or overpayment to Deposit Account No. 19-4880. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. 1.16 and 1.17 and any petitions for extension of time under 37 C.F.R. 1.136 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Priority is claimed from:

<u>Japanese Patent Application</u>	<u>Filing Date</u>
(patent) 81945/1999	March 25, 1999

Respectfully submitted,
SUGHRUE, MION, ZINN, MACPEAK & SEAS
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PA 406375

OPTICAL COMPONENT FIXING METHOD AND OPTICAL COMPONENT SUPPORT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an optical component fixing method and an optical component support for use in an optical apparatus equipped with at least one optical component and optical component support, particularly to a fixing method used when an optical component is fixed to a support by an adhesive and the support to which the optical component is fixed.

Description of the Related Art

In order to ensure stable laser emission, the length of the laser resonator must be kept from varying greatly with change in ambient temperature. This is achieved, for example, by temperature-controlling the resonator section. When the layer of adhesive between a resonator mirror and the retaining member is thick, however, thermal stress is produced by the difference in thermal expansion coefficient between the retaining member and the mirror. Since this increases the adhesive contraction during hardening, the resonator length cannot be kept constant. Change in the resonator length causes fluctuation in the laser output and the longitudinal mode and/or induces noise. Stable lasing cannot be maintained under these conditions. Change in resonator length therefore must be held to within 1/4 of the wavelength of the laser light. Considering the fact that many semiconductor-

laser-pumped solid state lasers emit light of a wavelength around $1\mu m$, change in resonator length should ideally be kept under around $0.25\mu m$.

Applicant's Japanese Unexamined Patent Publication No. 8(1996)-186308 teaches a Fabry-Perot resonator that has its resonator mirrors adhered to opposite ends of the resonator retaining member and that is enabled to maintain a constant resonator length by keeping the thickness of the adhesive layers at not greater than $5\mu m$ and the roughness of the machined surface of the retaining member at not greater than the wavelength of the laser light. In an optical apparatus that, like this semiconductor-laser-pumped solid state laser, requires precise positional adjustment and fixing of an optical component, the fixing of the optical component by use of a fluid adhesive must be carried out by uniformly flowing the adhesive between the optical component and its support. To ensure formation of a uniform adhesive layer, therefore, the practice is to facilitate the flow of the adhesive by finely polishing the attachment surfaces of the optical component and the support.

However, the fine polishing of the attachment surfaces of the optical component and support involves considerable cost and is therefore economically disadvantageous.

SUMMARY OF THE INVENTION

The present invention was accomplished in light of the foregoing circumstances and has as an object to provide a method for fixing an optical component and a support by a uniform

adhesive layer formed by flowing an adhesive between the optical component and the support, without need for finely polishing the attachment surfaces of the optical component and support.

The method of fixing an optical component according to the present invention comprises the steps of scoring a surface of a support, bringing an optical component into close contact with the scored surface of the support, and flowing a fluid adhesive along kerfs produced by the scoring.

By "flowing a fluid adhesive along kerfs produced by the scoring" is meant bringing the scored surface of the support and the optical component into close contact and allowing the fluid adhesive to seep along the kerfs by capillarity. By "adhesive" is meant any of various substances widely used to join two objects of the same or different types, including thermosetting adhesives composed of synthetic resins as well as other substances used for bonding such as solders, e.g., tin-lead alloy, and the like.

The pitch of the scoring kerfs is preferably 3μm-300μm. At less than 3μm, the scoring requires much time. At greater than 300μm, deep inflow of the adhesive by capillarity is hard to achieve. The depth of the scoring kerfs is preferably 0.1μm-1μm. Scoring kerfs of a depth of less than 0.1μm are difficult to form for technical reasons. A thin adhesive layer is hard to form when the depth of the scoring kerfs is greater than 1μm. Making the depth of the kerfs greater than 1μm is particularly disadvantageous in the case of a semiconductor-laser-pumped solid

state laser because it becomes difficult to reliably realize an adhesive layer thickness of 5μm or less as is necessary to ensure that the contraction during adhesive hardening does not affect the resonator length. The scoring tool used to effect the scoring, the relative motion between the blade and the scored object, the scoring technique (e.g., high-temperature scoring or low-temperature scoring) must be capable of conducting the scoring described in the foregoing but are otherwise not particularly limited. The scoring can, for example, be effected by a rotating blade.

The flatness of the attachment surface of the support is preferably 1μm or less, more preferably 0.3μm or less. When the flatness of the support is greater than this, the adhesive layer thickness cannot easily be kept at the aforesaid value of 5μm or less. By "flatness" is meant the fineness, including burrs, of the support attachment surface. The magnitude of the flatness is expressed as deviation of the surface from the reference surface owing to surface roughness, undulation, inclination or the like.

The optical component fixing method according to the present invention, i.e., the invention method of using an adhesive to fix an optical component and a support on which the optical component is to be fixed at a prescribed location, can be utilized in the case where the optical component is a component of a solid state laser apparatus, e.g., where it is a resonator mirror or other such component to be fixed on the support.

The invention support on which the optical component is fixed is characterized in that the surface thereof on which the optical component is fixed is provided with kerfs by scoring. The scoring kerfs are provided on the surface of the support at least at the portion thereof where the optical component is fixed.

The present invention provides a method of using an adhesive to fix an optical component and a support on which the optical component is to be fixed at a prescribed location. As the invention method comprises the steps of scoring a surface of the support, bringing the optical component into close contact with the scored surface, and flowing a fluid adhesive along kerfs produced by the scoring, it enables the adhesive to penetrate uniformly between the surfaces of the support and the optical component.

This effect of the invention is enhanced and the thickness of the adhesive layer can be minimized by forming the scoring kerfs to have a pitch of 3μm-300μm and a depth of 0.1μm-1μm and forming the attachment surface of the support to have a flatness of 1μm or less.

When the optical component is a component of a solid state laser apparatus, the aforesaid scoring of the support on which the optical component is fixed enables the adhesive layer joining the optical component and the support to be formed to a thickness at which the contraction during adhesive hardening does not affect the resonator length, even if the attachment surface is not finely polished.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic side view showing the overall configuration of a semiconductor-laser-pumped solid state laser in accordance with an embodiment of the present invention,

Figure 2 is an enlarged perspective view of the attachment section between a resonator mirror 14 and a holder 21 in accordance with an embodiment of the present invention,

Figure 3 is a front view of the attachment section shown in Figure 2,

Figure 4 is a sectional view taken along line A-A in Figure 2, and

Figure 5 is an enlarged plan view of a holder scored using a rotating blade.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be explained in detail with reference to the accompanying drawings.

Figure 1 shows a semiconductor-laser-pumped solid state laser in accordance with an embodiment of the present invention, Figure 2 is an enlarged perspective view of the attachment section between a resonator mirror 14 and a holder 21 in accordance with an embodiment of the present invention, Figure 3 is a front view of the attachment section shown in Figure 2, and Figure 4 is a sectional view taken along line A-A in Figure 2. The semiconductor-laser-pumped solid state laser includes a semiconductor laser 11, constituted as a chip, that emits a laser

beam used as optical pumping light, a condenser lens 12 for condensing the laser beam 10 (which consists of divergent light), a YAG crystal 12 (a solid state laser medium doped with neodymium (Nd); hereinafter called Nd:YAG crystal 12), and a resonator mirror 14 disposed on the front side (right side in the drawing) of the Nd:YAG crystal 13. A Brewster plate 15, a $KNbO_3$ crystal 16 (a nonlinear optical material; hereinafter called KN crystal 16) and an etalon 17 consisting of a quartz plate are disposed between the resonator mirror 14 and the Nd:YAG crystal 13 in the order mentioned from the side of the Nd:YAG crystal 13.

The semiconductor laser 11 emits a laser beam 10 of 809nm wavelength. The laser beam 10 enters the Nd:YAG crystal 13 where it excites niobium ions to emit light of 946nm wavelength. The end face 13a of the Nd:YAG crystal 13 through which the pumping light enters is covered with a coating that efficiently reflects light of 946nm wavelength (reflectance not less than 99.9%) and efficiently transmits the 809nm-wavelength pumping laser beam 10 (transmittance not less than 99%). The mirror surface 14a of the quartz resonator mirror 14 is covered with a coating that efficiently reflects 946nm-wavelength light and transmits 473nm-wavelength light.

The 946nm-wavelength light is therefore trapped between the surfaces 13a and 14a to produce lasing and the resulting laser beam is converted to 1/2 its wavelength, i.e., to the second harmonic 19 of 473nm wavelength, by the KN crystal 16, and the second harmonic 19 exits through the resonator mirror 14.

The semiconductor laser 11 and the condenser lens 12 are fixed on a holder 20. The Nd:YAG crystal 13, the Brewster plate 15, KN crystal 16, etalon 17 and resonator mirror 14 are fixed on a separate holder (support) 21. The holders 20 and 21 are fixed on a base plate 22 and the base plate 22 is fixed on a Peltier element 24. The surface member of the holder 21 is made of copper, for example, and, as shown in Figures 2-4, the portion 21b corresponding to the middle portion of the mirror 14 adhered to the holder 21 is formed with a notch. The end face of the holder 21 to which the mirror 14 is attached is scored perpendicularly to the notch to form a mirror attachment surface 21a.

The Nd:YAG crystal 13, Brewster plate 15, KN crystal 16, etalon 17 and resonator mirror 14 constitute a resonator. This resonator section, the semiconductor laser 11 and the condenser lens 12 are maintained at a prescribed temperature by the Peltier element 24 under the control of a temperature-regulation circuit (not shown).

<u>Example 1</u>

The mirror attachment surface 21a of the holder 21 was scored to form kerfs of 0.3μm-depth at a pitch of 10μm. The mirror attachment surface 21a was further ground in a fixed direction so as to make the size of the scoring burrs and the flatness 1μm or less. The peripheral portion 14b of the resonator mirror 14 and the mirror attachment portion 21b were brought into close contact. The resonator mirror 14 was then adhered to the the

holder 21 by using capillarity to cause dripped adhesive to penetrate into the gap between the two in the directions indicated by arrows in Figure 3. An epoxy adhesive of thermosetting was used. After the adhesive had penetrated between the attachment surfaces, the adhesive was allowed to harden by standing for 24 hours at room temperature and was then baked at 80°C for 12 hours.

The thickness of the adhesive layer between the mirror attachment surface 21a and the resonator mirror 14 measured after baking was about 1-2μm. The adhesive used in this example had a volumetric hardening contraction of 5-6%. Following storage tests conducted at between -25°C and +70°C after baking, the change in the thickness of the adhesive layers were found to be 0.1μm or less.

The change in the resonator length (distance between the end face 13a of the Nd:YAG crystal 13 and the mirror surface 14a of the resonator mirror 14) produced by the observed changes in the thickness of the adhesive layers was 0.2μm or less (not greater than 1/4 the 946nm wavelength of the solid state laser light). The wavelength change in this example was 0.01nm or less.

<u>Example 2</u>

Scoring was done using a rotary blade to impart a mirror attachment surface 25a with scoring as shown in Figure 5. A semiconductor-laser-pumped solid state laser was fabricated in the same manner as in Example 1 except that penetration of adhesive was effected in the direction of the arrows shown in

Figure 5. Change in thickness of adhesive layers after baking and storage tests conducted between -25°C and +70°C was found to be 0.1μm or less. The change in the resonator length (distance between the end face 13a of the Nd:YAG crystal 13 and the mirror surface 14a of the resonator mirror 14) produced by the observed changes in the thickness of the adhesive layers was 0.2μm or less (not greater than 1/4 the 946nm wavelength of the solid state laser light).

Comparative Example

A semiconductor-laser-pumped solid state laser was fabricated in the same manner as in Example 1 except that the mirror attachment surface 21a of the holder 21 was finished by ordinary milling. The thickness of the adhesive layer between the mirror attachment surface 21a and the resonator mirror 14 measured after baking was about 10μm. Change in thickness of adhesive layers after baking and storage tests conducted between -25°C and +70°C was found to be about 0.3μm (greater than 1/4 the 946nm wavelength of the solid state laser light).

Although this embodiment was explained regarding the fixing of the resonator mirror 14, the Nd:YAG crystal 13 is also adhered and fixed by the same method. While the invention was explained regarding an embodiment that uses a Nd:YAG crystal as the solid state laser and converts the solid state laser beam to its second harmonic, the invention can be applied with similar effect to semiconductor-laser-pumped solid state lasers that use other types of solid state laser crystals and, in particular, can be

applied to a semiconductor-laser-pumped solid state laser that does not conduct wavelength conversion. Moreover, the invention can also achieve the same effect by using high-temperature molten solder instead of the adhesive used in Examples 1 and 2.

What is claimed is:

1. An optical component fixing method using an adhesive to fix an optical component and a support on which the optical component is to be fixed at a prescribed location, the method comprising:

a step of scoring a surface of the support,

a step of bringing the optical component into close contact with the scored surface of the support, and

a step flowing a fluid adhesive along kerfs produced by the scoring.

2. An optical component fixing method according to claim 1, wherein the scoring kerfs are formed at a pitch of $3\mu m$-$300\mu m$.

3. An optical component fixing method according to claim 1 or 2, wherein the scoring kerfs are formed to a depth of $0.1\mu m$-$1\mu m$.

4. An optical component fixing method according to any of claims 1 to 3, wherein an attachment surface of the support has a flatness of $1\mu m$ or less.

5. An optical component fixing method according to any of claims 1 to 4, wherein the optical component is a component of a solid state laser apparatus.

6. An optical component support for fixing an optical component, the support comprising a surface provided with scoring kerfs for fixing the optical component.

ABSTRACT OF THE DISCLOSURE

A method of fixing an optical component includes the steps of scoring a surface of a support, bringing an optical component into close contact with the scored surface of the support, and flowing a fluid adhesive along kerfs produced by the scoring. An optical component support has a surface provided with scoring kerfs for fixing the optical component. The method and support enable fixing of an optical component by a thin, uniform adhesive layer, without fine polishing of the optical component and the surface of the support.

FIG. 1

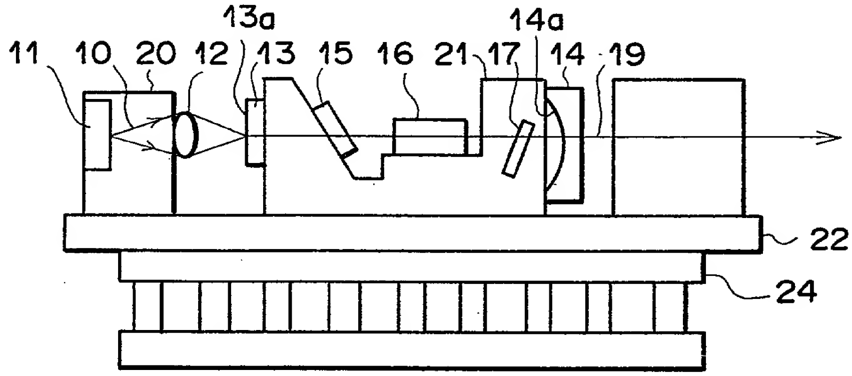


FIG. 2

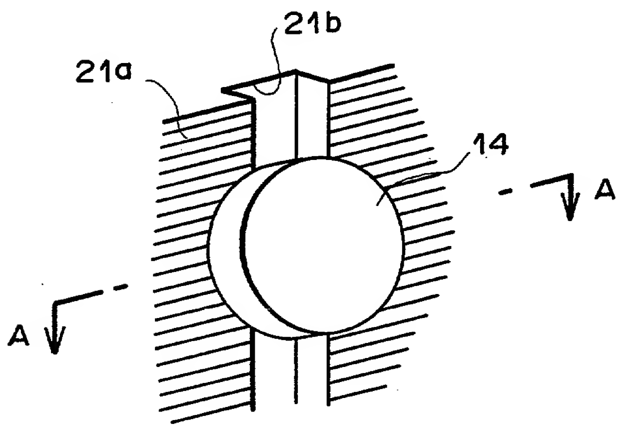


FIG. 3

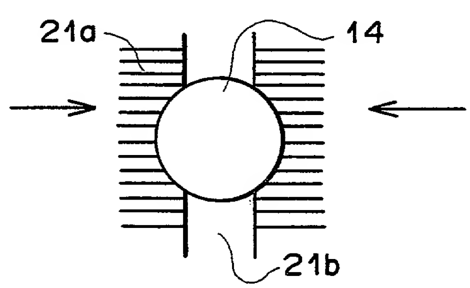


FIG. 4

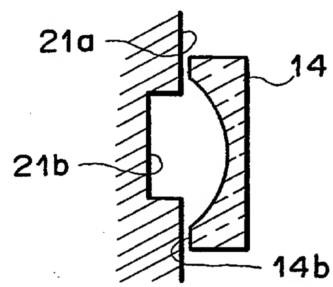
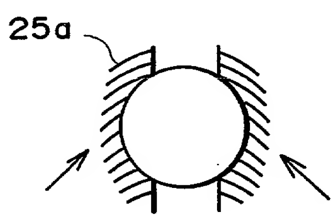


FIG. 5



PA 40639US

Declaration and Power of Attorney for Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

Hideo Miura and Kazumi Kubo

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name, c/o Fuji Photo Film Co., Ltd., 798 Miyanodai, Kaisei-machi, Ashigarakami-gun, Kanagawa-ken, Japan

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者(下記の氏名が一つの場合)もしくは最初かつ共同発明者であると(下記の名称が複数の場合)信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

"OPTICAL COMPONENT FIXING METHOD AND OPTICAL COMPONENT SUPPORT"

上記発明の明細書(下記の欄でX印がついていない場合は、本書に添付)は、

the specification of which is attached hereto unless the following box is checked:

☐ ___月____日に提出され、米国出願番号または特許協定条約

国際出願番号を ________________ とし、

(該当する場合) ________________ に訂正されました。

☐ was filed on ________________ as United States Application Number or PCT International Application Number ________________ and was amended on ________________ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration

（日本語宣言書）

私は、米国法典第35編第119条(a)-(d)項又は第365条(b)項に基き下記の、米国以外の国の少なくとも一カ国を指定している特許協力条約第365条(a)項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Applications
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Not Claimed 優先権主張なし
(patent) 81945/1999	Japan	25/03/1999	☐
			☐
			☐

私は、第35編米国法典119条(e)項に基づいて下記の米国特許出願規定に記載された権利をここに主張致します。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Application No.) (出願番号)	(Filing Date) (出願日)

私は、下記の米国法典第35編第120条に基づいて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約第365条(c)に基づく権利をここに主張します。又、本出願の各請求範囲の内容が米国法典第35編第112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内又は特許協力条約国際出願提出日までの期間中に入手された、連邦規則法典第37編第1条第56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit of Title 35, United States Code Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose any material information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

私は、私自身の知識に基づいて本宣言書中で私が行う表明が真実であり、かつ私の入手した情報と私の信ずるところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行えば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration

（日本語宣言書）

委任状： 私は、下記の発明者として、本出願に関する一切の手続きを米国特許商標局に対して遂行する弁理士又は代理人として、下記のものを指名致します。（弁護士、又は代理人の氏名及び登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith *(list name and registration number)*

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(202)293-7060

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第二発明者の署名 日付	Second inventor's signature Date Kazumi Kubo March 21, 2000
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（第三以降の共同発明者についても同様に記載し、署名をすること。） (Supply similar information and signature for third and subsequent joint inventors.)